INTERNATIONAL SOLDIER SYSTEMS CONFERENCE AND EXHIBITION 2004

Photovoltaic Power-Generating Textiles

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The Science Behind the Warrior: Yesterday, Today and Tomorrow

Photovoltaics for Lightweight, Conformal and Renewable Power

(Go Farther, Stay Longer, Be Lighter)

Problem: ***Current power sources are heavy, expendable and detectable, not directly integratable into Warrior Systems, and do not have sufficient density for extended missions.***

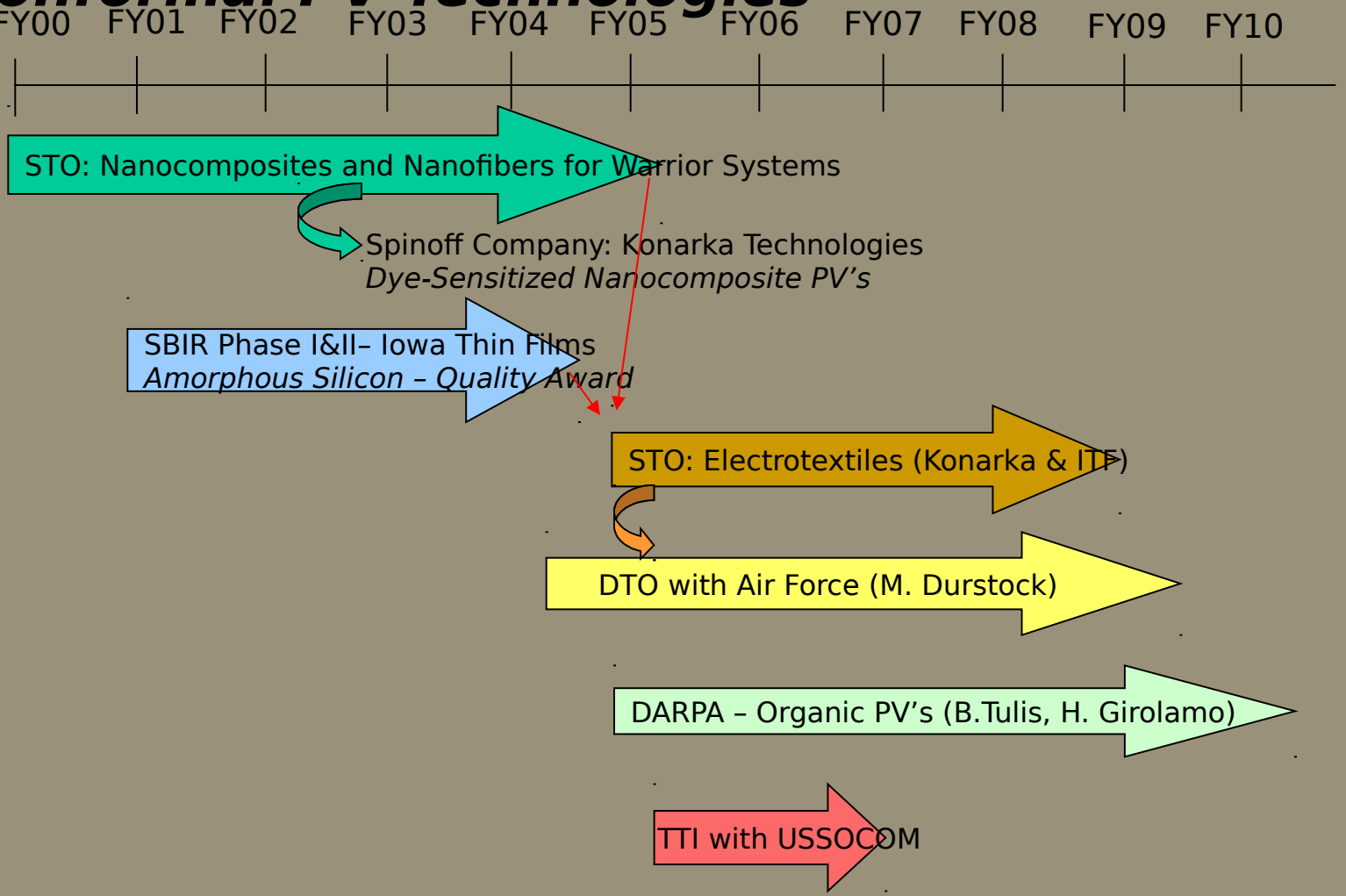
Known – Photovoltaics (PV) convert "free" light energy into electricity with no noise, moving parts, fuel consumption or pollutant emissions.

Less known – PV technology has changed significantly over recent years… technology that now allows for PV's that are flexible and lightweight!

Photo courtesy DOE/NREL

Today's PV's can provide many benefits to the military…..

Natick Soldier Center Photovoltaic Efforts
Roadmap Towards New Lightweight and Conformal PV Technologies



Potential Advantages of PVs

- Reduce Soldier's Load while supplying renewable power.

Projected weight reduction of >50% when PV used in combination with rechargeables.

- Improve Sustainability - Extend Mission, Farther and Longer (>3 d
- Stealthy– Silent, minimal visible and movement signatures
- Reduction of logistical supply tail & minimize vulnerability to loss of fuel / energy lines
- User Friendly – less labor, maintenance and training
- Less of a heat signature than generators, ***No Acoustic Signatur***
- Clean Energy – no emissions, pollutants (*200,000 lbs pollution eliminated)
- Cost Reductions:

- Batteries, *Fuel, logistics of resupply, maintenance,…

*U.S. Army ADAPT – Analysis of Deployment Applications of PV in Theater. 2kW trailor mounted PV wi 5kW gasoline powered generator (MEP017A). PV provided 80% of tactical power, MEP802A augmente remaining demand.

Applications – Tailor selected surfaces to generate power

- **Battery Rechargers**
  - Portable (BB2590, AA's)
  - Stationary – kW's power from larger surface area structures (sh vehicles-manned and unmanned)

- **Hybrid Power**
  - Complement to Generators – U.S. Army ADAPT Report
  - Tandem Cell for hydrogen production from water for fuel cells

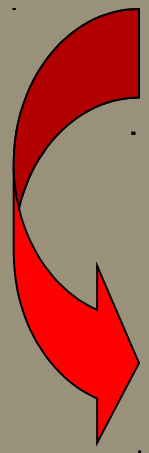
- **Modular Power Units** - provide pockets of power, minimize wires/connects
- **Couple with Batteries** for "Anytime Power"

- **Emergency Back-up** – Save Lives

Versatile: Tailored to meet mission requirements

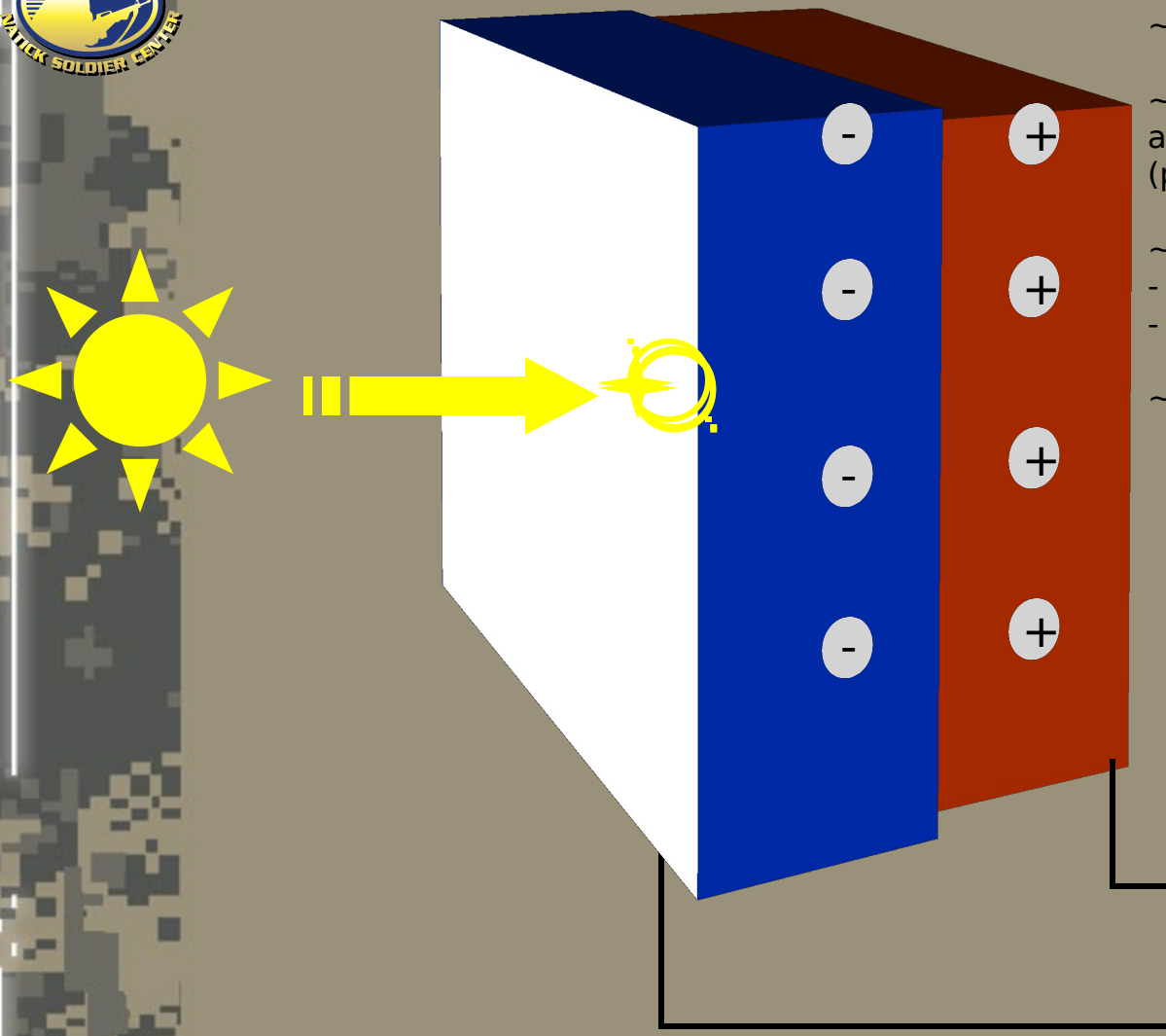
How

- Improvements to either existing technologies or developm of new materials that can provide sufficient photoelectric conversion efficiency to make practical devices feasible
- Develop these technologies to process these materials into durable true textile based architectures for lightweight Soldier Systems



- Iowa Thin Films – Amorphous Silicon
- Konarka Technologies – Dye Sensitized Nanocomposi

Amorphous Silicon PV

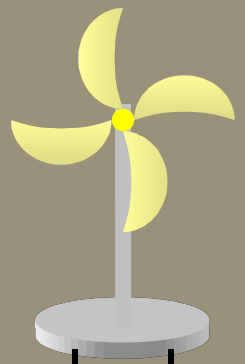


~ Photons impinge on semiconductor

~ Excites electrons (valence to conduction b
and creates electron-hole pairs
(pairs of – and + carriers)

~ At p-n junction of doped semiconductor:
- Electrons migrate towards (+)side of junct
- Holes toward (-)side

~ Leading to a flow of current.



SBIR Phase II Summary

- Developed three new fabric structures integrated with PV
- Developed and implemented new laser scribing system giving
  600% throughput improvement.
- Developed and implemented roll based lamination giving
  2400% throughput improvement.
- Developed military and commercial spin offs.

SBIR Quality Award Winner !!!

SBIR Prototypes: PV Technology Ready to Transition

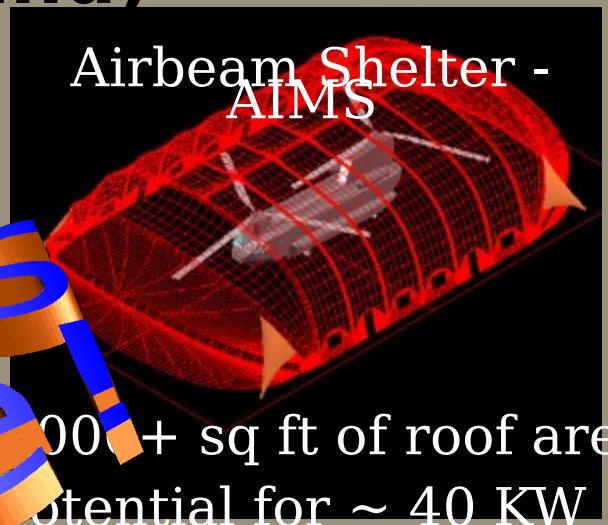
Portable and PV Shelter Products to Augment Bare Base Shelter Systems

(Video Production by Rob Hawley, Strategic Communications

Soft Shelter Applications (PV Opportunities Abound)

Aviation LAMS

Supports OIF and OEF
Supplements/Replaces Buildings
17,000+ sq ft of roof area
Potential for ~ 40KW



Airbeam Shelter - AIMS

00+ sq ft of roof area
otential for ~ 40 KW !

That's Huge!

CP-DEPMEDS Field Hospital

Potential for 60KW+ by using PV TEMPER flys alone!

Keep Critical Systems Up

~1KW

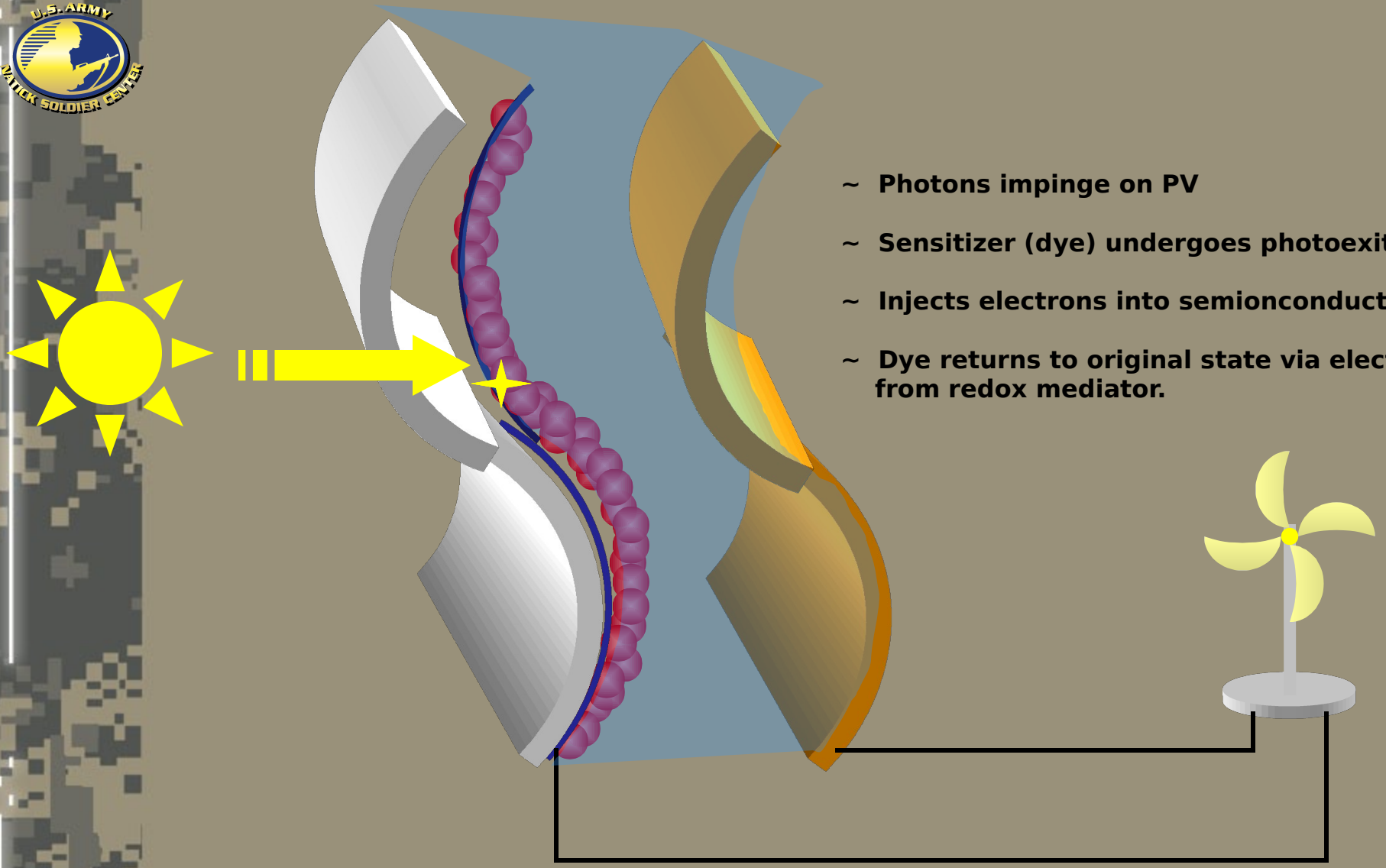
~5KW

~6KW

~7 KW

- Solar Shades -
Some >1 Acre Complexes!

Dye-Sensitized Nanocomposite PV



- Photons impinge on PV
- Sensitizer (dye) undergoes photoexitatio
- Injects electrons into semionconductor (T
- Dye returns to original state via electron from redox mediator.

STO: "Conducting Nanocomposites and Nanofibers For Warrior Systems"

Objective: To develop a next generation, nano-based PV devices for lightweight and conformal, renewable power generation. Designed to extend power generation into new frontiers/applications where traditional devices cannot be used (plastics, fibers, textiles…)

New Mind Set:
Instead of covering object with the PV, make the object from a PV

Combine: Recent "In-house" Developed Technologies From:

Natick Soldier Center (Materials Science Team)

&

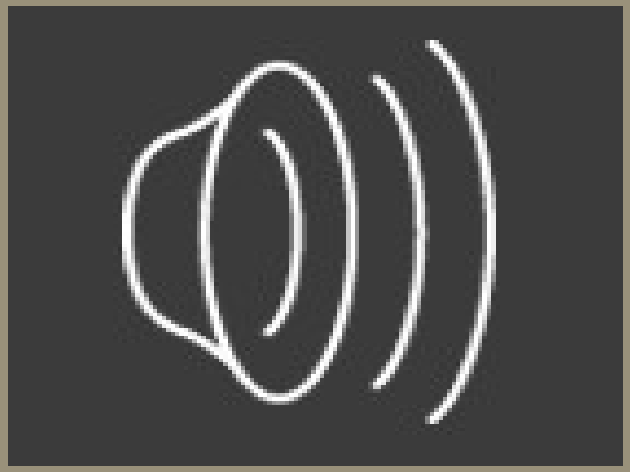
University of Massachusetts Lowell

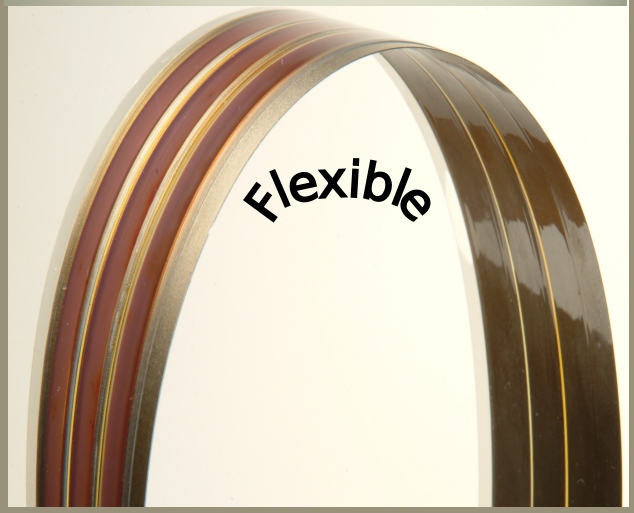
Konarka Technologies – Spin-off Company

Next Generation PV's
Dye Nanocomposite PV Technology

Now

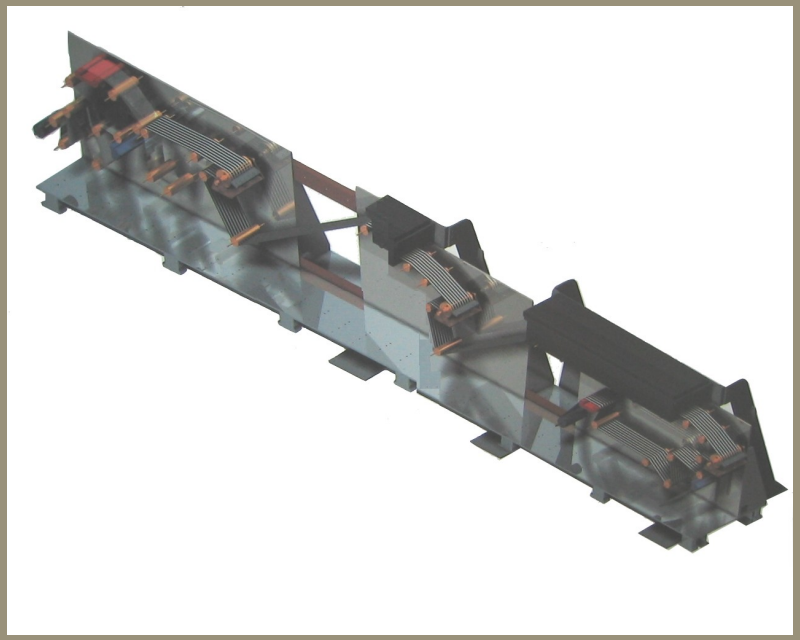
Early Work
From Glass to
Plastic…





Because of unique nanotechnology, these PV devices are lightweight, conformal and amenable to facile, versatile and low cost processing…..

Process – Roll to Roll Coating



Simple – no clean rooms, vacuums

*Engineering Versatility –
Custom make to suit specific applications

Scalable –
Uses known coating/printing technologies and existing equipment/facilities

Cost

Performance Numbers to Date for Manufactured Devices:

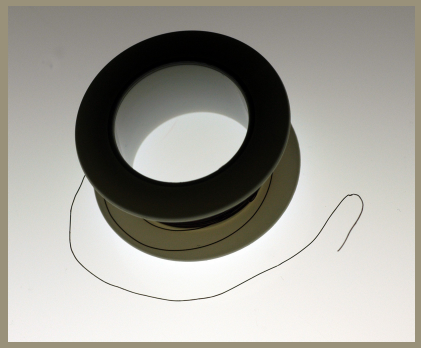
Power Output @ AM1.5 (full sun): *50 W/sq m, 4.65 W/sq ft*
Weight: < 0.1lbs/sq ft, >40 W/lb
Lifetime > 10 years (IEC/IEEE Standard)

New Concepts Unique to this Technology…..

"Camo" Patterned PV's **– to minimize visible signature**

Dye sensitizers themselves make the pattern….not a mask!

First Known Nanocomposite PV Fiber



P/V Fibers to PV Textiles for……

portable devices, shelters, vehicles, ….soldier borne wearable electronics

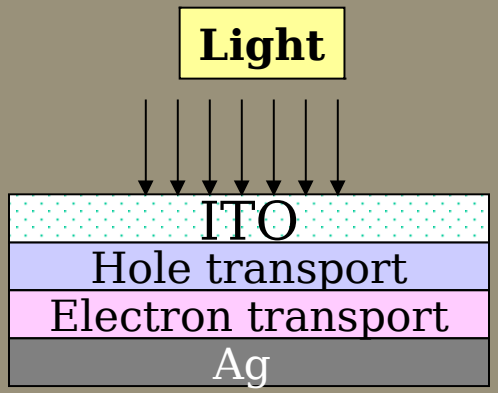
Flexible Nanocomposite Organic Photovoltaic Cells Program

(DARPA PM B. Tulis, Dep. PM: J. Peak, NSC PM of 2 of 4 teams: H. Girolamo)

"Revolutionary Improvements in PV Technology"

Goal

- Demonstrate significant advances in photovoltaic device performance utilizing nanocomposite organic cells.
- Provide military with flexible, lightweight, durable, and low-cost solar cells.



Performance Objectives

- Increase power-to-weight ratio by 200X
- Solar to electrical conversion efficiency of greater than 20%
- Flexible solar panel (bend around a 1 cm radius)
- Lightweight (0.1kg/m2)
- Enhanced environmental stability (3 months continuous operation)

Push efficiencies to the limit with organic based PV devices
Yet maintain all the advantages of organic based materials…

Versatility – Recharging and Direct Power

Capability Concepts

Recharging Stations

Portable Power

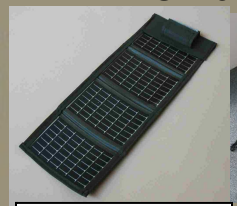
Animations by Steve Smith
Strategic Communications, NSC

On-Going & Future Efforts

FY05 FY06 FY07 FY08 FY09

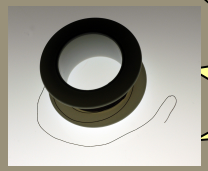
Improve Efficiencies, Stability, Conformability

Portable PV Mats



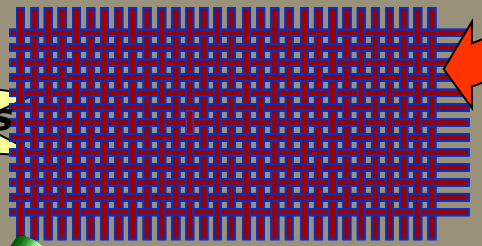
AA Battery Charger

5, 10, 20 W Roll-able



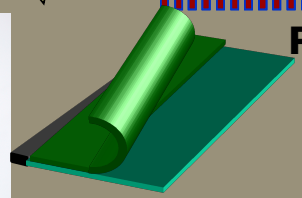
PV Fibers

New concepts



PV Textiles

Camouflage PVs

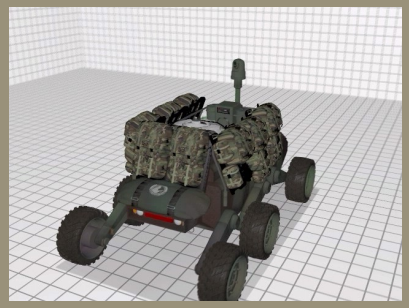


PV/Battery All in One Device

PV Standardized Evaluations
- Tyndall AFB (M. Keith)
- Arizona State University

Wearable Electronics

Other Applications – Eg. UGV



PV Integrated Shelters